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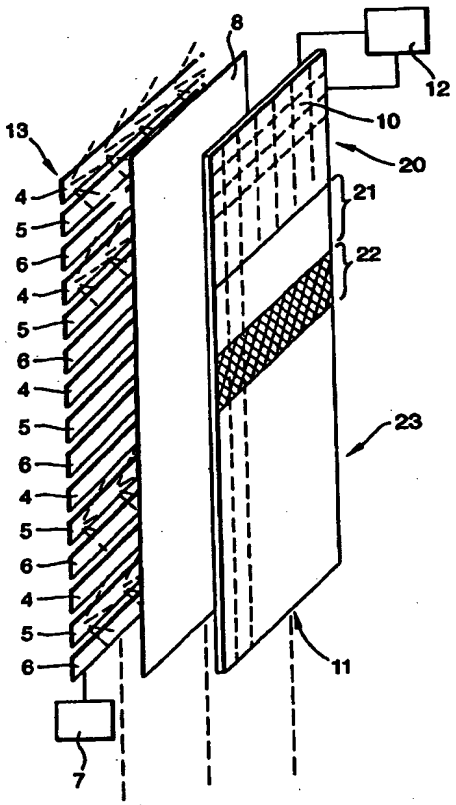
(54) Title: BLACKLIGHT CONTROL FOR A DISPLAY DEVICE

(57) Abstract

A display device comprises a matrix (11) of pixels (10) arranged in rows and columns, each pixel (10) being selectively settable into a light transmissive condition and an opaque condition, and an illumination system, comprising an array of elongate elements (4, 5, 6) which provide light in response to electrical impulses, the elements (4, 5, 6) being arranged side by side to give a striped appearance and to face the matrix (11). Adjacent elements provide light having a different one of a plurality of colours. The matrix (11) is addressed using a row by row addressing sequence. During part of this sequence, a row of pixels (10) is illuminated with light of a first colour from a first element, whilst a remote row of pixels is illuminated with light of a different colour from a further element. This enables more efficient illumination of the matrix (11) than with conventional colour sequential displays in which all rows are illuminated with the same colour at the same time.



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BLACKLIGHT CONTROL FOR A DISPLAY DEVICE

Background of the Invention

This invention relates to a display device comprising a matrix of pixels arranged in rows and columns, each pixel being selectively settable into a more light transmissive condition and a less light transmissive condition, means for addressing the pixels using a row by row addressing scheme, and an illumination system. It relates particularly to display devices (known as colour sequential displays) in which a given pixel is illuminated with different colour light at different times to form an image having a plurality of colours.

A number of display devices are known which use a technique known as colour sequential lighting to produce multicolour displays from intrinsically monochrome non-emissive displays such as liquid crystal displays. One such device is disclosed in EP-A-0 261 896. This particular device suffers from the disadvantage that the display can only be illuminated when it is not being updated. As most displays take a significant period of time to update (known as the frame time) the final image is usually only illuminated for a small fraction of the frame time, resulting in a display having a low brightness.

A colour sequential display which can be illuminated during updating is disclosed in EP-A-0 478 186. Although this display mitigates the above problem, the display device must still be in the non-light transmissive state for an average of 50% of the time, which still results in a display having a less than optimum brightness.

Brief Summary of the Invention

According to a first aspect of the present invention, there is provided a display device as claimed in claims 1 to 11.

According to a second aspect of the present invention, there is provided an illumination system for a display as claimed in claims 12 to 16.

The present invention enables more efficient illumination of the matrix than with conventional colour sequential displays in which all rows are illuminated with the same colour at the same time or in the same frame time, as it provides the

ability to illuminate spaced rows with different colours during a single frame time.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which:-

Figure 1 shows an oblique view of a display device according to the present invention; and

Figure 2 shows the light output from the display device of Figure 1 at successive times.

Detailed Description of the Invention

Figure 1 shows an oblique view of a display device according to the present invention. The display device comprising a matrix (11) of pixels arranged in rows and columns, each pixel (10) being selectively settable into a more light transmissive condition and a less light transmissive condition, means (12) for addressing the pixels using a row by row addressing scheme, and an illumination system comprising an array (13) of elongate elements (4, 5, 6) which provide light to the matrix in response to electrical impulses, the elements being arranged side by side to give a striped appearance and to face the matrix, adjacent elements providing light having a different one of a plurality of given colours, and means (7) for providing electrical impulses to the elements in a predetermined sequence which is synchronised with the row by row addressing scheme.

In the present embodiment the pixels comprise an electro-optic material, such as for example a layer of a ferroelectric liquid crystal sandwiched between substantially transparent row and column electrodes which are orthogonal to one another and which overlap to define the pixels. The array (13) of the illumination system comprises a striped backlight, the elements of the array including an electroluminescent material, such as for example a light emitting polymer. Each stripe or element of the array provides one of a plurality of different given colours, in the present embodiment either green light (elements identified by the reference numeral 4), red light (5), or blue light (6), in response

to respective electrical signals from the circuit arrangement (7) comprising the backlight drive means.

A conventional sequential display is disclosed in International Patent Application No. WO 9633483 (Cambridge Display Technology Limited). Each pixel in the pixel array is sequentially addressed and, as a result, only one colour (for example either red, green or blue) may be displayed at a time. This is less efficient than the display disclosed in the present invention, where more than one colour may be displayed simultaneously.

The array of electroluminescent elements is formed into a substantially planar structure which is arranged to face the matrix of settable pixels in use. An optional diffuser (8) is provided in the path of light from the array (13) to the matrix (11). The presence of this diffuser reduces the striped appearance of the display in use. The diffuser may, for example, comprise a ground glass screen.

The display device of figure 1 is operated in the following way. To begin with, no elements of the illumination system are on (i.e. no elements are providing light to the matrix). Data is written onto the matrix one row at a time, starting with the top row. This means that electrical data pulses are provided by the pixel drive means (12) on the column electrodes of the matrix, whilst an electrical addressing pulse is provided on the top row electrode. It is important that the electro-optic material comprising the matrix is able to respond to provide optically distinguishable conditions in pixels being addressed with different data within a few line times. An element at the top of the array comprising the illumination system is then switched on to provide light to the matrix. The colour of this element corresponds to the colour information represented by the data that has been written onto the top row of the matrix. The row second to top of the matrix is then written with information corresponding to the same colour as that of the first row. The addressing is then repeated on the next adjacent row of the matrix with information corresponding to the same colour.

When a number of rows have been first addressed in this way such that the next row to be addressed is closer to the next element of the illumination system having the same colour as that of the first element, then this next element is switched on in addition to the first, and the process is repeated for subsequent

rows until the whole matrix has been addressed and is being illuminated by all the elements of the array having a given colour.

What then happens is that the top row or rows of the matrix are blanked into the less light transmissive condition, and the top element of the backlight array is turned off. In practice, several rows of the matrix will be blanked and a plurality of elements of the backlight array having the same colour will be switched off before new data corresponding to different colour information is written to the top row of the matrix. This is done so as to prevent or minimise the light from elements having one colour to diffuse or leak into other elements in the array providing different colours. In Figure 1, area 20 is being illuminated with green light from elements 4, the area 21 is not being illuminated at that point, area 22 is blanked such that the pixels are in the less light transmissive condition, and area 23 is being illuminated with red light from elements 6.

The brightest and most efficient display is produced when the blanked area (22) is kept as small as possible compatible with the minimisation of light leakage mentioned above. The size of the blanked area must be sufficiently large for the rows to have sufficiently blanked and the electro-optic material to have had sufficient time to recover before new data is written. This may be expressed as a time, which for the Hoechst AEG 4851 material used in the embodiment described above is of the order of 400 μs.

The actual width of the blanked area (22) will depend on the precise design of the illumination system. It may be possible for either the un-illuminated part of the backlight array (21), or the blanked area (22) of the matrix where the pixels are in the less light transmissive state to be of almost zero height. The important feature is for there to be some substantially dark area between parts of the matrix being illuminated simultaneously with light having different colours (i.e. areas 20 and 23).

After the top part of the display has been blanked as described above, new data is written to the top row or rows of the display. This new data corresponds to information representing a different colour. The element of the backlight array nearest to the top of the display providing the appropriate colour of light is then switched on. The sequence carries on as before until all the rows have been addressed and written with data representing information having this new

colour, and all the elements of the backlight array having the same colour have been switched on. If only two colours were being used the whole process would then start over again from the beginning. However, if a third colour is to be written, the process is repeated for that colour in an analogous way. The sequence of events described above results in light outputs from the display device as shown in Figure 2 (a) to (f) at successive times during the addressing sequence.

In order to keep the update rate high enough to avoid noticeable flicker and to keep the line time as long as possible (to minimise power consumption and power dissipation), at any given time a row should always be being addressed. Therefore, as soon as the last line of the display is completed, the top line is immediately re-written. This implies that the top rows of the display have already been blanked before the last rows have finished being written to. If there is no restriction on the speed at which the display operates, it may be desirable to have a period of time between when the last row is written with data and the whole display is illuminated with a single colour ,and the start of the addressing sequence writing data to the first row representing information of the next colour in the sequence.

Although in the above description the display started off by being completely blank, this is not a necessary requirement, as the first colour will be quickly written to the whole matrix it is not important what the display was displaying beforehand. It is also possible to start the addressing from the bottom row of the matrix and working upwards.

The above display device can provide an advantage over prior art display devices because the length of time a given part of the display is dark can be made small relative to the frame time, so that the display appears to be much brighter than conventional displays.

The number and width of the elements of the backlight array are arranged such that in combination with the diffuser the striped appearance of the display is minimised and the spreading of the light be the diffuser is kept to a minimum. It is important that if there are N given colours of backlight array element, each element is constructed and arranged to illuminate at least N rows of the display,

as there will be N-1 elements having different colours between nearest neighbour elements having the same colour.

It is desirable, but not essential, that the matrix is constructed such that it is capable of having one row blanked whilst another is being written at the same time, in order to keep the rate at which data needs to be written to a minimum. A ferroelectric liquid crystal layer is an example of an electro-optic material which is capable of being operated in this way. As an alternative, the blanking and writing may be done in turn.

The display device described above may advantageously be used with alternative addressing schemes, such as the time weighted grey scale addressing schemes disclosed in EP-A-0 261 901 and EP-A-0319291, which are hereby incorporated into this application by reference.

Figure 3 shows an example of an addressing sequence according to a 3 bit binary weighted scheme for a 7 row display which achieves 8 grey levels and which is described more fully in EP-A-0 261 901. Each horizontal line in this Figure corresponds to a row in the display. Each square in the horizontal direction represents the time taken to address a single row. The numbers 1, 2, and 3 in each row in the central area show the binary significance of the of the data which is being written (1 denoting the least significant bit and 3 the most significant bit). The position of these numbers in the vertical direction show which row is being addressed , whilst the horizontal position of these numbers shows the time period in which the addressing is taking place. The dark vertical lines show at what time each frame ends for each row. In a conventional colour sequential display the dark vertical line between successive frames would represent the time when one colour backlight(which would illuminate all the rows at the same time) would be switched on and the previous one would be switched off. However, in Figure 3 the vertical lines appear at different times for different rows as it relates to a monochrome display in which physically adjacent rows are not next to one another in the row address sequence.

If colour sequential backlighting is combined with a time weighted grey scale scheme (as described for example in EP-A-0 319 293) then there is usually a significant period of time during which most parts of the display are dark, resulting in a relatively dim display. New information corresponding to that for

a different colour can only start to be written onto the matrix when every row of the previous colour field has been on for the duration required to achieve the correct time weighting. This is prior art scheme is shown in Figure 4(a). This shows the same scheme as shown in Figure 3 and described above, except for the fact that the row positions have been rearranged so that the first addressing of a row is such that the sequence of such first addressing can be written progressively from top to bottom (or bottom to top). It is an important feature of the present invention that the first addressing of a row in a given frame moves progressively through physically adjacent rows. This feature is not an essential element of time weighted grey scale schemes *per se*.

It can be seen from inspecting Figure 4(a) that almost a third of the available pixel on-time does not result in light output, because although the backlight is illuminating the pixels, they are in the less light transmissive condition, shown shaded in Figure 4(a). The thin black areas between frames indicate when the backlight is being switched from one colour to the next.

The result of combining the display device of the present invention with the time weighted grey scale addressing scheme described above is shown in Figure 4(b). Much less time is spent with pixels illuminated whilst being in the less light transmissive condition. Table 1 below shows the result of calculations showing the percentage of the frame time that rows are blank for the prior art scheme of EP-A-0 319 293 for various numbers of bits of grey scale information and the present invention.

Number of bits	Blank line times (prior art)	Blank line times (present invention)	% time blank (prior art)	% time blank (present invention)
2	3	2	33.0	25.0
3	11	3	34.4	12.5
4	31	4	34.1	6.3
5	79	5	33.8	3.1
6	191	6	33.5	1.6

TABLE 1

As can be seen from this table, the display device of the present invention has a much higher percentage of time when the pixels output useful light, resulting in

a significant brightness advantage over the prior art scheme, especially when many grey levels are employed.

Although in the above embodiments the array of elements comprising the illumination system comprised an electroluminescent material such as for example a light emitting polymer, other materials such as light emitting organic or inorganic materials may be used as an alternative. The elements do not have to be electroluminescent providing that they are capable of emitting light (or reflecting or scattering light) in response to an electrical impulse. In particular the elements may comprise an electrochromic material or a polymer dispersed liquid crystal modulator, together with an appropriate light source.

CLAIMS

1. A display device comprising a matrix of pixels (11) arranged in rows and columns, each pixel (10) being selectively settable into a more light transmissive condition and a less light transmissive condition, means (12) for addressing the pixels using a row by row addressing scheme, and an illumination system comprising an array (13) of elongate elements (4, 5, 6) which provide light to the matrix (11) in response to electrical impulses, the elements (4, 5, 6) being arranged side by side to give a striped appearance and to face the matrix, adjacent elements providing light having a different one of a plurality of given colours, and means (7) for providing electrical impulses to the elements (4, 5, 6) in a predetermined sequence which is synchronised with the row by row addressing scheme, characterised in that during part of the predetermined sequence, one or more adjacent rows of pixels (10) are illuminated with light of a first colour from a first element, whilst one or more other rows of pixels (10), spaced from the one or more adjacent rows, are illuminated with light of a different colour from a further element spaced apart from the first element.

2. A display device as claimed in claim 1 in which adjacent elements which provide light having different colours do not provide such light to the matrix (11) at the same time.

3. A display device as claimed in claim 1 or claim 2 in which the number of rows being illuminated by an element is equal to or greater than the number of given colours.

4. A display device as claimed in any preceding claim in which the row by row addressing scheme is such that successive adjacent rows of pixels (10) being provided with light of a given colour are first addressed in successive address periods.

5. A display device as claimed in claim 4 in which each row in the matrix (11) is addressed a plurality of times whilst being illuminated with light of a given colour, the time intervals between successive addressings of a given row forming a geometric progression having a common ratio which is at least 2, thereby providing a plurality of brightness levels.

6. A display device as claimed in any preceding claim in which the pixels (10) comprise an electro-optic material.

7. A display device as claimed in any preceding claim in which the pixels (10) comprise a ferroelectric liquid crystal material.

8. A display device as claimed in any preceding claim in which the elements (4, 5, 6) comprise an electroluminescent material.

9. A display device as claimed in claim 1 to claim 7 in which the elements (4, 5, 6) comprise an electrochromic material.

10. A display device as claimed in claim 1 to claim 7 in which the elements (4, 5, 6) comprise a polymer-dispersed liquid crystal modulator.

11. A display device as claimed in any preceding claim in which a diffuser (8) is provided in a path of light from the illumination system to the matrix (11).

12. An illumination system for a display, the system comprising an array of elongate elements (4, 5, 6) which provide light in response to electrical impulses, the elements (4, 5, 6) being arranged side by side to give a striped appearance, adjacent elements providing light having a different one of a plurality of given colours, and means (7) for providing electrical impulses to the elements (4, 5, 6) in a predetermined sequence.

13. An illumination system as claimed in claim 12 in which the predetermined sequence is such that at given times in the sequence, elements (4, 5, 6), which are spaced from one another physically, simultaneously provide light having different respective colours.

14. An illumination system as claimed in claim 12 or claim 13 in which the elements (4, 5, 6) comprise an electroluminescent material.

15. An illumination system as claimed in claim 12 or claim 13 in which the elements (4, 5, 6) comprise an electrochromic material.

16. An illumination system as claimed in claim 12 or claim 13 in which the elements (4, 5, 6) comprise a polymer-dispersed liquid crystal modulator.

Fig.1.

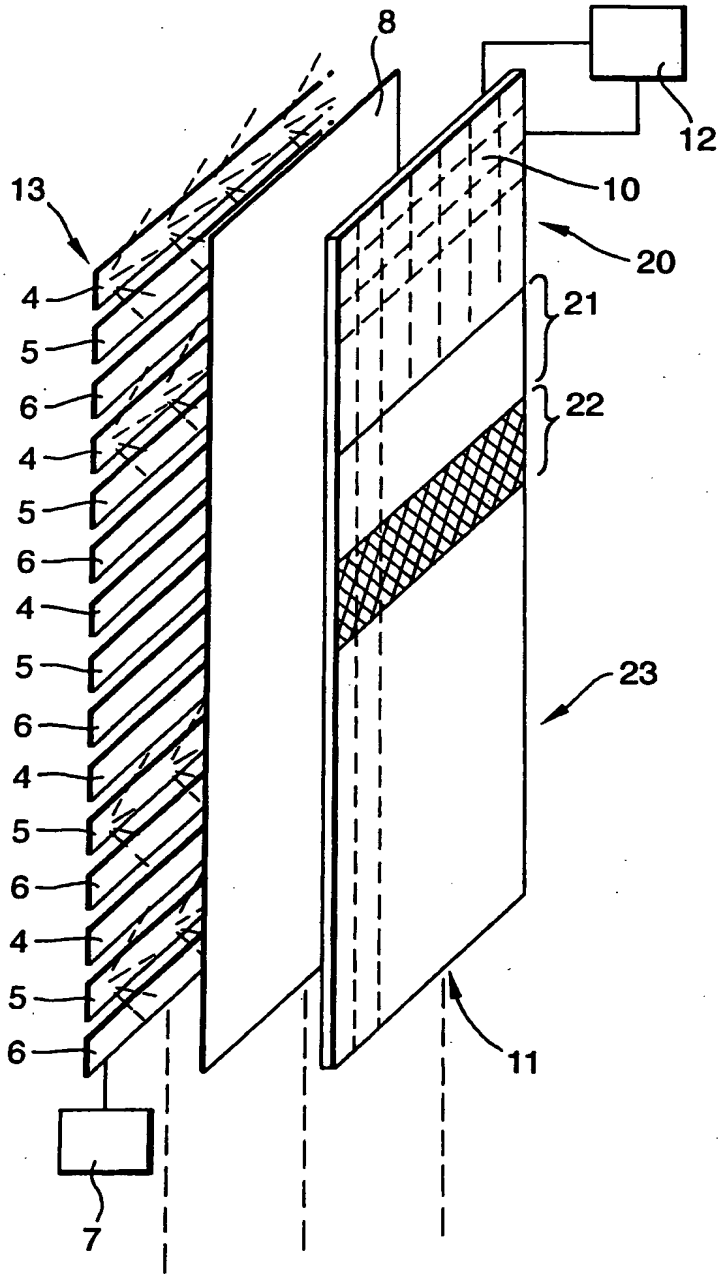


Fig.2(a)

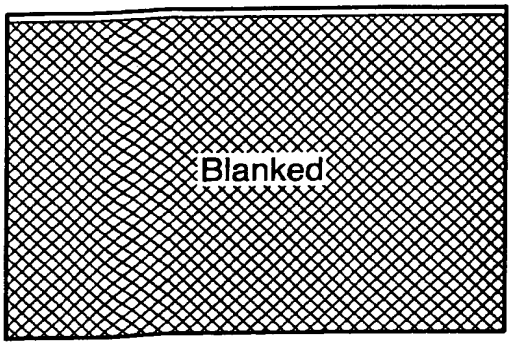


Fig.2(b)

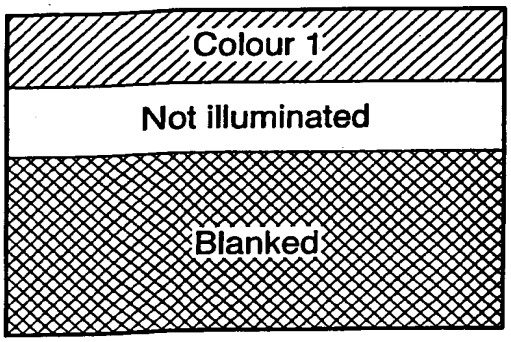


Fig.2(c)

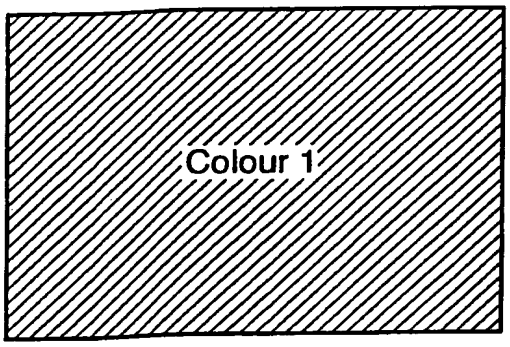


Fig.2(d)

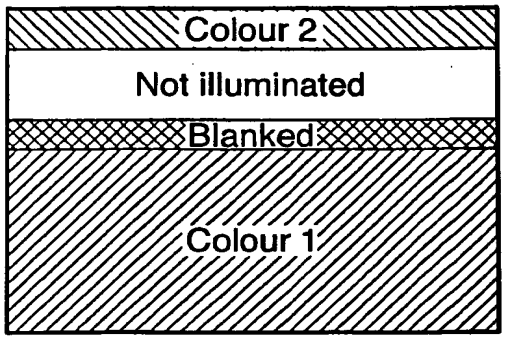


Fig.2(e)

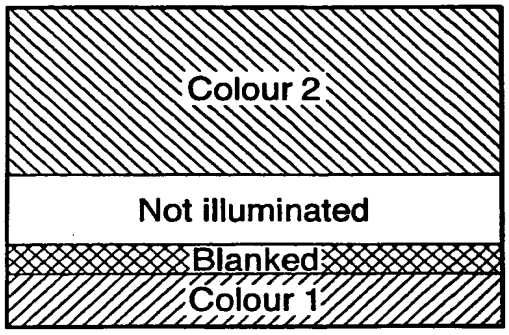


Fig.2(f)

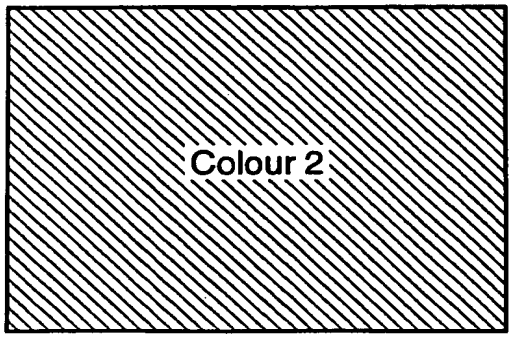
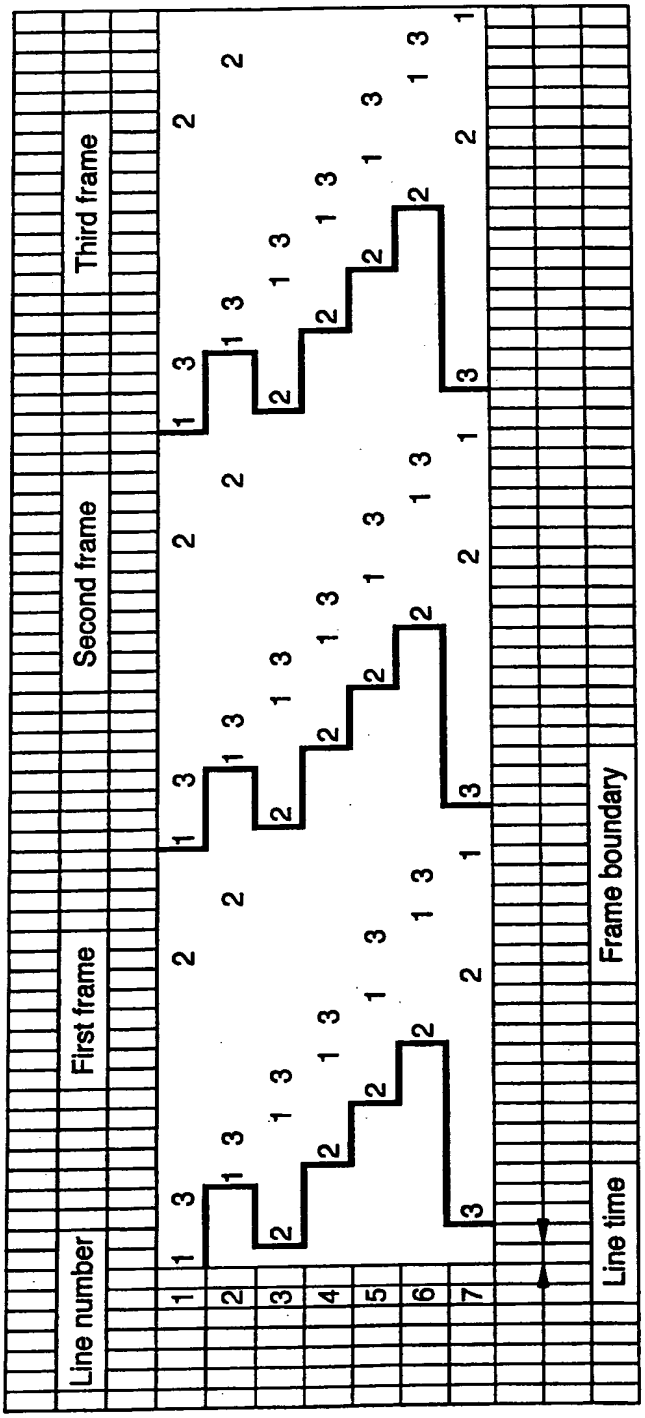


Fig.3.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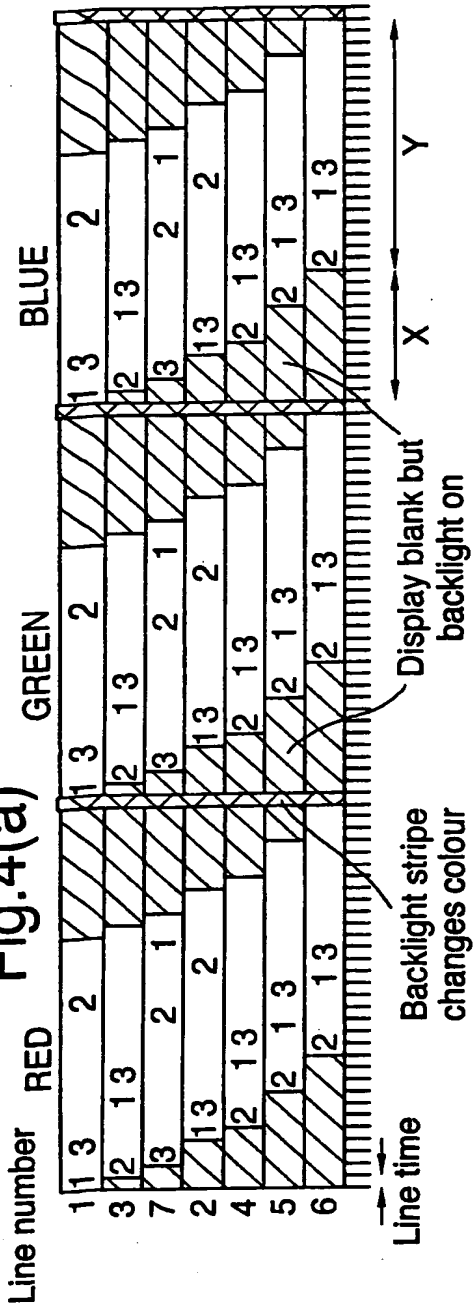

Fig.4(a)

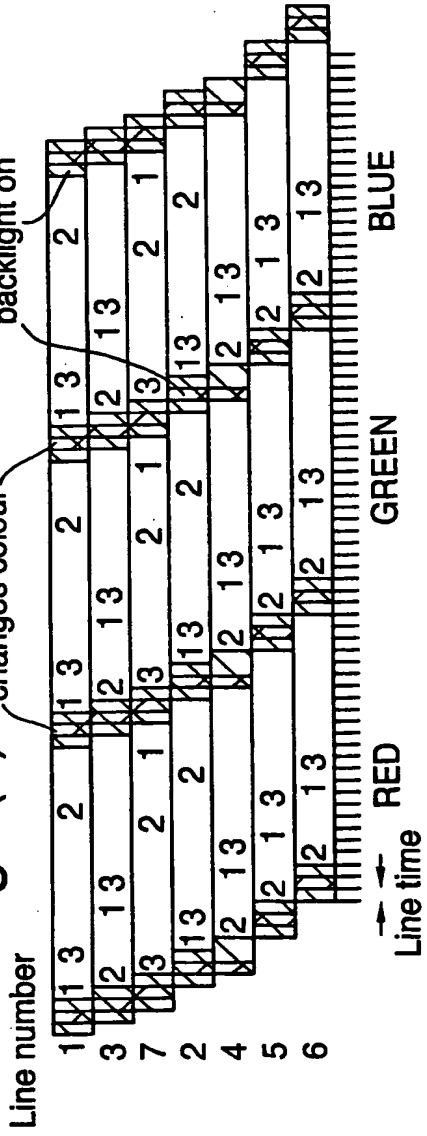

Fig.4(b)

INTERNATIONAL SEARCH REPORT

Inter onal Application No
PCT/GB 99/00934

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G09G3/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 121 233 A (SPENCER GORDON R ET AL) 9 June 1992 (1992-06-09) abstract; figures 1-4 column 5, line 63 - column 7, line 24	1-4,6, 11-13
X,P	PATENT ABSTRACTS OF JAPAN vol. 098, no. 012, 31 October 1998 (1998-10-31) & JP 10 186311 A (SONY CORP), 14 July 1998 (1998-07-14) abstract	1-4,6,12
A	WO 96 19082 A (PHILIPS ELECTRONICS NV ;PHILIPS NORDEN AB (SE)) 20 June 1996 (1996-06-20) page 6, line 12 - page 10, line 3	1-4,12, 13

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☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
27 July 1999	03/08/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van Roost, L

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5121233 A	09-06-1992	NONE	
JP 10186311 A	14-07-1998	NONE	
WO 9619082 A	20-06-1996	US 5644357 A	01-07-1997
		EP 0745309 A	04-12-1996